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PHOTOELECTROCHEMISTRY OF ELECTRONIC AND ELECTRO-OPTICAL MATERIALS

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The broad objective of this work is to investigate applications of photoelectrochemistry to semiconductor and electro-optical technology. Experiments are being undertaken to understand the functions of reaction velocity and crystallographic orientation in determining profiles and morphologies of photoelectrochemically etched features in Si, SiC and III-V compounds. Work was also conducted to determine the relationship between liquid junction response and solid state diode electrical characteristics of the polar faces of III-V crystals and to develop chemical surface passivants for compound semiconductor device electronics.

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SUMMARY

The broad objective of this work was to investigate applications of photoelectrochemistry to semiconductor and electro-optical technology. Experiments were undertaken to understand the functions of reaction velocity and crystallographic orientation in determining profiles and morphologies of photoelectrochemically etched features in Si, SiC and III-V compounds. Work was also conducted to determine the relationship between liquid junction response and solid state diode electrical characteristics of the polar faces of III-V crystals and to develop chemical surface passivants for compound semiconductor device electronics.

Photoelectrochemical Etching. Much of the program entailed studies of the photoelectrochemical fabrication of periodic grating structures in GaAs and SiC. We discovered that the effects of crystal structure and orientation can be used to manipulate microstructural geometry. For example, photoelectrochemical etching can be used to produce V-grooves in GaAs crystals using crystallographically oriented photoresist masks on the electrode surface; process parameters can be used to control groove angle and morphology. Other crystallographic orientations give rise to high aspect ratio grooves (e.g., 1:100) in compound semiconductors with geometries dictated solely by the directionality of the photon flux.

Photoelectrochemical Surface Processing. Part of our work has been devoted to studying chemical and photoelectrochemical surface treatments of III-V semiconductors and their effects on solid state device structures. Experiments were conducted to replace the mixed Ga,As,O oxides used currently on GaAs with a heavy metal sulfide that will result in a stable surface devoid of Fermi level pinning. We had considerable success with HgS. Preliminary experiments employing complex impedance analysis of the surfaces were carried out in order to understand the effects of the sulfides on solid state device electrical characteristics, particularly MOS structures.

Practical Significance. During this program we completed a review of photoelectrochemical processing of semiconductors, which includes a discussion of some applications of the technique. In addition, several new applications of photoelectrochemistry have arisen from this work and are currently being pursued in mission-oriented projects for DoD and other agencies. Following are several examples of components that may be fabricated photoelectrochemically:

- V-groove (Echelle) diffraction gratings for high resolution spectrometers.
- SiC diffraction gratings for vacuum ultraviolet spectroscopy, (e.g., synchrotron light source).
- Robust gratings for high energy laser beam steering (e.g., SDI, free electron laser).
- Diffraction gratings in III-V compounds for electro-optics (e.g., distributed feedback lasers, coupling to multi-quantum well photodetectors).

- Mesh-type optical filters for far infrared/millimeter wave regions (infrared astronomy, meteorology, surveillance optical systems).
- Fiber optic couplers to solid state photodiodes.
- Front/backside via interconnects (high aspect ratio, narrow holes).
- Selective electroplating via walls.
- High resolution custom markings of ICs (1-5 μm alphanumerics).
- Controlled gate fabrication for GaAs and InP FETs.
- Passivation of semiconductor surfaces, particularly for III-V MOSFETs.

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PUBLICATIONS

1. "The Cadmium Chalcogenides (CdS, CdSe, CdTe)", in Studies in Physical and Theoretical Chemistry vol. 55: Semiconductor Electrodes, H.O. Finklea, ed. (New York/Holland: Elsevier Publishing Co., 1988), pp. 277-327.

2. "Photoelectrochemical Etching of Blazed Echelle Gratings in n-GaAs", presented at the Fall Meeting of the Electrochemical Society, Chicago, IL, October 9-14, 1988.

3. "Photoelectrochemical Etching of Blazed Echelle Gratings in n-GaAs", J. Electrochem. Soc. **135**, 1370 (1988).

4. "Photoelectrochemical Fabrication of Gratings in SiC", Fall Meeting of the Electrochemical Society, Hollywood, FL, October 15-20, 1989.

5. "Morphology Control of Photoelectrochemically Etched Profiles in n-GaAs", presented at the Fall Meeting of the Electrochemical Society, Hollywood, FL, October 15-20, 1989.

6. "The Evaluation of Photoelectrochemically Etched Gratings in GaAs" Space Optics for Astrophysics and Earth and Planetary Remote Sensing Topical Meeting, North Falmouth, MA, September 27-29, 1988 (with NASA).

7. "Photoelectrochemical Processing of Semiconductors" in Electrochemistry of Semiconductors and Electronics, J. McHardy and F. Ludwig eds., (Noyes Publications, Park Ridge, NJ, 1992), pp. 177-212.

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